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ABSTRACT

A review is made of that literature which focuses on the relationship of instructional method, internal cognitive activity and performance measures. This includes literature concerned with the issue of "discovery versus reception learning" and the effects of different instructional methods on retention, delayed retention and transfer tasks. The author concludes from this review that little progress will be made concerning our understanding of the role of instructional method until the emphasis on "which method is best" gives way to an attempt to define and relate to one another, external features of instruction, internal features of subject character and activity during learning, and outcome performance variables. (JP)

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LEARNING TO SOLVE PROBLEMS:

ROLL OF INSTRUCTIONAL METHOD AND LEARNER ACTIVITY

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SE 017 805

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The Problem

Suppose you wanted to teach someone to solve problems of a given class. What kind and how much direction should be given during the learning process? Or suppose someone has been taught to solve problems of a given class. Does the teaching method that was used influence the learning outcome?

These sorts of questions represent the core of what could be called "the instructional method problem" -- the problem of ascertaining the relationship between certain aspects of the instructional method (the independent variable) and subsequent performance on related or identical tasks (the dependent variable). Shulman (1968, p. 34) summarized the problem as follows: "The controversy seems to center essentially about the question of how much and what kind of guidance ought to be provided in the learning situation."

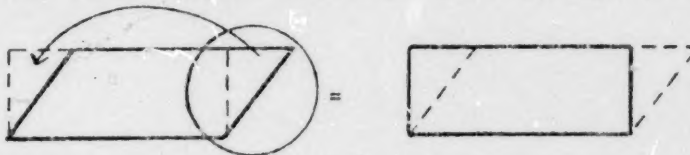
This is not a new problem and there have been many attempts to deal with it. However, as Wittrock (1966, p. 33) pointed out in a recent review of the evidence concerning the ambiguous "learning by discovery" method: "Many strong claims for learning by discovery are made in educational psychology. But almost none of these claims has been empirically substantiated or even clearly tested in an experiment."

The Background

Before discussing how such claims could be tested experimentally, some background will be presented to demonstrate some distinctions involved in the claims. Though often poorly and inconsistently defined, a basic distinction between (at least) two different types of teaching methods has long been a component of theories of instruction.

The gestalt psychologists distinguished a type of instruction that fostered "structural understanding" from instruction that involved "rote memory" (Wertheimer, 1959), "meaningful apprehension of relations" from "senseless drill and arbitrary associations" (Katona, 1940), "insight" from "trial and error" (Kohler, 1959), or "productive" from "reproductive" reasoning (Maier, 1933; Wertheimer, 1959). Unfortunately, however, the gestaltists never clarified their various distinctions, often confused differences in instructional method with differences in the subsequent problem solving approach, and provided little or questionable empirical support for their claims.

The flavor of their distinction can be found in an example by Wertheimer (1959) suggesting two methods of teaching Ss to find the area of a parallelogram. One method emphasizes the geometric or structural property that the triangle on one end of the figure could be placed on the other end of the figure thus forming a rectangle (see below):

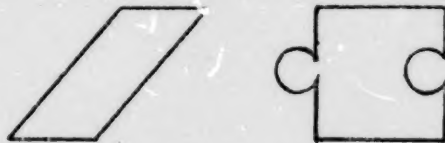


The other method emphasizes a sort of cook-book recipe of steps to calculate the area, namely drop the perpendicular and multiply its height times the length of the base (see below):



Although Ss taught under both methods should perform equally well on criterion tasks involving finding the area of parallelograms like the ones they were taught about, Wertheimer reported the Ss differed in their ability to transfer what they learned to new tasks. For example, the Ss who learned "by understanding" (the first method) should be able to find

the area of unusual parallelograms and shapes, e.g.

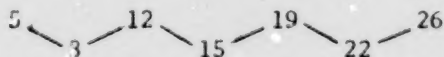


and recognize uncalculable situations, e.g.



while the Ss who learned in a mechanical way (the second method) would say, "We haven't had this yet."

In an example of memorizing digit strings, Katona (1940) claimed that learning by "understanding the structural relationships" not only improves S's ability to transfer but also improves S's ability to retain information over time. One group learned the digit string, 581215192226, by understanding the structural pattern of "add 3, add 4" as indicated below,

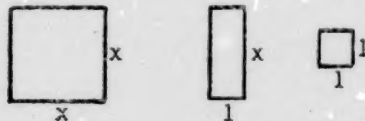


while another group learned by "rote memorization" of the string organized as 581-215-192-226. Although both groups performed equally well on criterion tests of immediate retention, Katona reported that the first group remembered the string longer.

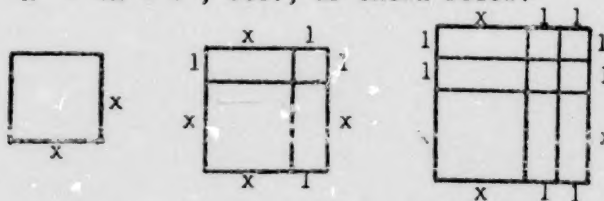
In more recent years, the distinction has taken the equally ambiguous form of a separation between "discovery" and "expository" methods of instruction. Bruner (1961, 1963a, 1968) has been a major proponent of the discovery method. Although often describing discovery both as an instructional method and as a desired outcome of learning, and although seldom empirically defining either, Bruner's preferred method of instruction is, at least, exemplified in a procedure proposed by Dienes (see Shulman,

1968).

Dienes' method of teaching children the concept of the quadratic equation involved allowing S to manipulate the shapes,

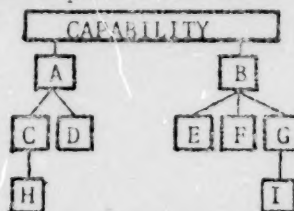


in such a way that S could see that the area of a square with sides of length x was x^2 , of sides $(x + 1)$ was $x^2 + x + x + 1$, of sides $(x + 2)$ was $x^2 + 4x + 4$, etc., as shown below:



The discovery method shares with the Gestalt "learning by understanding" the promise of superior transfer and retention performance by the learner.

On the other hand, Gagné and his associates (Gagné, 1968; Gagné, Mayor, Carstens & Paradise, 1962) have been major proponents of a more expository method often called "guided discovery". The method involves a clear and behaviorally defined statement of the instructional objective and a hierarchical enumeration of what S needs to know in order to have the defined capability, as represented in a "knowledge hierarchy" below:



The prerequisite concepts, principles, definitions, etc., must be hierarchically defined such that in order to perform the required "capability", S must know A and B; in order to know A, S must know C and D; in order to know C, S must know H; and so on. Teaching then involves systematically presenting S with prerequisite knowledge, beginning at the

lowest level of S's incompetence and building up.

As Shulman (1968) pointed out, Bruner's emphasis is on the process of learning while Gagné's emphasis is on the product of learning. Bruner's method stresses the acquisition of a general ability to discover problem solutions while Gagné's method is more closely tied to specific capabilities in dealing with specified subject matter. Bruner's method tends to force errors and subsequent "restructuring" by S while Gagné's programmed instruction presents a smooth, systematic hierarchy of knowledge thus minimizing the chances of error.

The Analysis

As can be seen from this representative array of largely untested examples and claims, the following are needed: (1) a clear definition of the external features of the instructional methods, (2) an understanding of Ss internal activity during learning, (3) a set of observable performance measures for learning and learning outcomes, (4) an experimental procedure for determining the relationship among these variables.

External dimensions: Many methodological problems stem from unsatisfactory definitions of the independent (instructional) variables. As Wittrock (1966, p. 42) pointed out, many studies conceptually confuse, for example, "discovery as a way to learn" (i.e., as an independent variable) and "discovery as an end in its own right" (i.e., as a dependent variable), or label external instructional variables (independent variables) in terms of the internal responses or behavior such methods are thought to evoke (dependent variable).

All too often, inadequate definitions have accompanied not only a confusing of independent variable and dependent variable, but also a lumping together of several variables into one. The often cited discovery-expository

dichotomy as the instructional variable is actually a family of variables and any serious attempt to investigate instructional method effects should recognize the various variable dimensions involved.

Although sometimes only implicitly defined as such, the main instructional variables have been: (1) amount and type of direction, e.g., ranging from no guidance as to how to solve representative examples up to explicit enumeration of the correct solutions, (2) sequencing of direction, e.g., ranging from inductive example-rule procedures to deductive rule-example procedures, (3) continuity or structuring of direction, e.g., ranging from highly discontinuous, unstructured procedures that encourage errors to smooth, hierarchically arranged methods that minimize the chances of subject error, and (4) control of direction, e.g., ranging from total subject control over the rate and order of presentation (as attempted by "adaptive teaching systems") to total experimenter control.

In a recent review, Hermann (1969) separated the amount of direction (e.g., discovery vs. reception) from the sequencing of direction (e.g., inductive vs. deductive) and represented the various variables in a 2 x 2 matrix, as shown.

	Discovery	Reception
Inductive	A	B
Deductive	C	D

The discovery-reception dimension is defined in terms of the amount of direction with the discovery methods involving minimum direction in which "...the principle content of what is to be learned is not given..." and the reception method involving maximum direction in which "...the entire content of what is to be learned is presented to the learner in final form...". Wittrock (1963) has further analyzed the dimension taking into account not only the amount, but also the kind of information given

(or not given). The amount of information about the final answer can be varied (e.g., from none to detailed presentation of the answer in final form); similarly, the amount of information about the method or principle used for solution can be varied (e.g., from none to hints or outright presentation of the solution method).

The inductive-deductive dimension is defined in terms of the sequencing of direction with deductive methods involving a direct statement of the to-be-learned rule or principle followed by example applications for S to try -- or as Glaser (1966, p. 15) put it, "...a teaching sequence in which a rule is presented before exemplars or instances of the rule..." -- and inductive methods involving the reverse ordering. Hermann (1969) pointed out that in terms of the existing research literature, cell C of his matrix is empty.

The third dimension was discussed by Glaser (1966) as a distinction between smoothly guided teaching programs, such as Gagné's (1968) "learning hierarchy" model, based on the principle of "error minimization" and more unstructured, discontinuous procedures such as Davis' (1958, 1966) "torpedoing" techniques which increase the chances of S committing errors in learning. From the standpoint of "reinforcement theory" Skinner (1953) distinguished between teaching by "small steps" between adjacent items and teaching by "large steps" between adjacent items with the former supposed to elicit far fewer errors, hence more reinforcement in learning.

Finally, the fourth dimension involving control of direction has been mentioned by several investigators (e.g., Wittrock, 1966; Bruner, 1961) and is defined in terms of the number and kinds of constraints put on S's access to the learning materials.

Internal dimensions: In contrast to these external dimensions of the

instructional method, there are certain internal or intervening dimensions of the learner which should be considered. The internal dimensions can be separated into: (1) the level of various learner characteristics established prior to learning, and (2) the amount and kind of cognitive activity evoked during learning.

The first set of internal dimensions, which acts as an independent variable, is that of learner characteristics. Several researchers (e.g., Cronback and Snow, 1969; Tallmadge and Shearer, 1971) have reviewed and investigated the often contradictory role of such individual difference factors as intelligence, ability, experience, personality, anxiety, age, sex, motivation and others. Also, there exists a classical gestalt literature (e.g., Duncker, 1945; Luchins, 1942; Saugstad and Raahiem, 1960; Birch and Rabinowitz, 1951) on the importance of past experience in learning to solve problems. Because the individual differences literature represents a large, fairly self-contained area, it will not be specifically reviewed herein.

The second important set of internal dimensions, one which should properly be viewed as a dependent variable, is S's activity, especially S's cognitive activity during learning. Rothkopf (1970) wrote of the influence of instructional method on S's "mathemagenic activities" during learning, activities which he related to such concepts as set, attention, orienting reflex, information processing, cognition and rehearsal. Rothkopf (p. 325) argued: "The proposition is simple. In most instructional situations, what is learned depends largely on the activities of the student."

Gagne (1958, 1966, 1969) has outlined a series of "internal conditions for problem solving" which include "search and selection" of existing knowledge. He has suggested that "what is learned" involves both "external events" such

as instructional materials, instructions, and direction, and "internal events" such as the nature of this "trial and error", "hypothesis selection", or "search and selection" activity.

Arguing from a somewhat different approach, Ausubel (1961, 1964, 1968) wrote of S's "learning set" and suggested that learning outcomes are determined both by "content conditions" (i.e., presentation of the to-be-learned material) and "set conditions" (i.e., the existing cognitive structures S uses to assimilate the content). Ausubel proposed that S may store content material in either a rote or meaningful way depending on S's ability to relate subject matter content to existing cognitive structures, i.e., depending on whether the "content" is encoded into a "rote learning set" or into a wider "meaningful learning set". The point is summarized as follows (1961, p. 95): "As long as the set and content conditions of meaningful learning are satisfied, the outcome should be meaningful and the advantages of meaningful learning (economy of learning effort, more stable retention and greater transferability) should accrue irrespective of whether the content to be internalized is presented or discovered, verbal or nonverbal."

Another argument for separating external and internal dimensions comes from Bruner and his associates (Bruner, Goodnow and Austin, 1956) who have demonstrated the importance of S's "strategy" in CI tasks and have shown that differences in this internal encoding process are evident in transfer performance. The nature of the internal search and selection process is at the crux of Bruner's (1966) "compatibility problem" -- "the problem of how to get a new piece of knowledge connected with an established domain."

Scandura (1966, 1967) has attempted to delineate experimental variables influencing how broadly S encodes mathematical rules or algorithms.

For example, in a problem solving task, Ss given the solution algorithm in conjunction with very specific applications performed significantly better on near transfer items than Ss not given the algorithm, but performed significantly worse on far transfer than Ss given the algorithm with more general applications. In another study, Ss learning problem solution rules in symbolic notation could apply them just as well as Ss learning the same rules in plain English, only if they had received pretraining in what the symbols meant. The evidence supports the claim that although all Ss learn the same content (i.e., problem solving rules), internal factors such as a broader assimilative "set" do influence transfer performance.

According to Roughead and Scandura (1968, p. 288, "what is learned" due to these broader cognitive sets is "derivation rules" -- "rules for deriving a class of more specific rules". Simon and Simon (1962, p. 429) presented evidence for the same sort of learning outcome differences due to internal "trial and error" activity during S's learning to play chess: "The evidence strongly suggests that expert chess players discover combinations because their programs incorporate powerful selective heuristics and not because they think faster or memorize better than other people."

One possible derivation of the separation of external (instructional) variables from internal (set) variables is that different methods of instruction could evoke different internal sets or activities in S and hence different learning outcomes. The point was summarized by Mayer and Greeno (1972, p. 165): "...different instructional procedures could activate different aspects of existing cognitive structure. And since the outcome of learning is jointly determined by new material and the structure to which it is assimilated, the use of different procedures could lead to the develop-

ment of markedly different structures during the learning of the same new concept."

A crucial question at this point becomes: How can the internal cognitive set and activities of the learner be characterized? A number of defining factors have been noted with respect to these internal events during learning, and generally the distinctions among various types of internal activity during learning involve: (1) S actively participates in the discovery of the to-be-learned principle or material vs. S passively receives the material in final form, (2) S stores and organizes the material in his own way vs. S stores and organizes the material as E has organized it, (3) S assimilates the material to a wide range of existing cognitive structures vs. S accomodates his existing structures to the material, (4) S strives to acquire a high level general rule or strategy vs. S strives to acquire discrete, specific responses to specific situations.

Bruner (1961, p. 24) in his classic paper entitled "The act of discovery" discussed these distinctions between types of internal events during learning, especially the first one:

Very generally, and at the risk of oversimplification, it is useful to distinguish two kinds of teaching: that which takes place in the expository mode and that which takes place in the hypothetical mode. In the former, the decisions concerning mode and pace and style of exposition are principally determined by the teacher as expositor, the student as listener...in the hypothetical mode the student is in a more cooperative position...the student is not a bench-bound listener, but is taking part in the formulation...and may even take an 'as if' attitude.

The second distinction between internal activities is reflected in Bower's (1970) separation between "experimenter-imposed grouping" (E-codes) and "subject-imposed groupings" (S-codes). The assimilation-accomodation distinction (i.e., the third part) follows with slight modification from Piaget's (1970) original usages. The final distinction

deals with S's interpretation of what should be learned as discussed by Rosenthal (1966) and Orne (1962).

One way of summarizing the distinctions in internal activity is to differentiate the degrees to which S searches through existing knowledge in order to map the presented material into superordinate organizing systems. The key to a resolution of the instructional method problem eventually rests in a more intense analysis of this distinction or set of distinctions, between an active, assimilative self-coding, rule-generating cognitive process vs. a more passive accommodation to E's coding system and specific responses.

There are very few experimental studies that deal directly with this issue of internal cognitive activity and its relationship to instructional method and performance measures; and for the most part, reviewers can only hypothesize about what S was doing during learning. However, some hint as to the importance of S's behavior during learning is reflected in a study by Gagné and Smith (1962) in which a major variable was whether or not S was instructed to verbally search for a justification of each move in learning to solve a problem. The problem was the Ewert and Lambert (1932) "disc problem" or what Ernest and Newell (1969) called the "tower of Hanoi problem": given three circles arranged in a triangle with some number of discs in circle 1 arranged in order of size with the smallest on top, the problem is to move the discs from circle 1 to circle 2 in the least number of moves, moving the discs one at a time and never putting a larger disc on top of a smaller one.

The solution involves learning the general principle: "If the number of discs is odd, move first to the circle that you want to go to eventually; if even, move first away from this circle. Continue by moving

discs with odd numbers always in a clockwise direction, and discs with even numbers always in counter-clockwise direction." The Ss learned to solve the 2-disc, 3-disc, 4-disc, and 5-disc problems under the following conditions: (1) Group V-SS in which S was instructed to verbally state why he made each move and to think of a general principle involved, (2) Group V which involved just the instruction to verbalize, (3) Group SS which involved just the instruction to think of a general principle, and (4) Group No which received neither instruction.

All Ss eventually learned to solve all the problems with Group SS and Group No taking less time but making slightly more excess moves. However, on a transfer test comprised of the 6 disc problem in which no verbalizations were required, Ss who had verbalized during learning performed significantly better than non-verbalization Ss. The effect due to instructions to think were not significant. However, it is known that effects of this kind of variable can be reliable; Duncan (1963), using a different problem task, reported significant effects due to "think" instructions.

The performance of Ss on the 6-disc problem is summarized below:

	Groups			
	V-SS	V	SS	No
Mean Excess Moves	7.9	9.3	48.1	61.7
Mean Time to Solution (min.)	4.2	3.8	10.1	10.0

Ss who vocalized during learning also were better able to state the solution principle. Six of the 14 Ss in the verbalization group could state the complete principle as opposed to none of the 14 non-verbalization Ss.

There are several possible explanations why forcing S to verbalize while practicing the three-circle problem resulted in superior transfer and ability to state the general principle. One interpretation is that the verbalization Ss were more active during learning; the requirement

to verbalize forced them to search their existing cognitive structures for justification of their moves. Gagné and Smith (p. 17) stated the influence of verbalization on internal cognitive activity as follows: "Requiring verbalization somehow forced the Ss to think."

Performance dimensions: In addition to the relatively undeveloped measures in internal activity during learning -- a factor only partially reflected in measures of learning difficulty such as time or errors to criterion -- several important measures of learning outcomes have been established.

The most common measures have been: (1) retention, including immediate and longer term ability to perform the learned task; (2) transfer, including the ability to apply the learned material to new problems both near to and far from original examples. Others include (see Cronbach, 1966): "conviction" or "adherence to a principle in a confusing stimulus situation", "rationale" or the ability to explain a principle in terms of other concepts, "interest" in the learned material as indicated by questionnaire responses, "savings" in learning a related problem solution, and ability to "verbalize" the rule or principle involved.

Procedure: In order to determine the relationship among external (instructional), internal (cognitive), and performance (outcome) dimensions, an experimental procedure must be developed. Katona (1940) was one of the first to explicitly propose a paradigm whereby previously unknown problem solutions would be taught by two or more different methods to an equal criterion, as summarized below (p. 7):

STAGE 1	STAGE 2	STAGE 3
Not knowing A or being able to perform A.	Application of learning method I. Application of learning method II.	Knowing A or being able to perform A.

The fourth stage involves taking performance measures of learning difficulty and outcome.

Cronbach (1966) has suggested some features that limit the generality of instructional method experiments. They include the nature of the subject matter, the age and other characteristics of the subjects, the specific type and amount of instruction, the specific outcome variables employed, and the size and scope of the design. Most of the studies reviewed in this paper involve problem solving situations such as decoding anagrams, choosing the item that doesn't belong, learning mathematical principles, learning card tricks and matchstick problems. Researchers using more conventional materials have called into question the generality of findings regarding these "puzzle type problems" and have indicated that instructional method effects may be due largely to the type of material used.

Most of the subjects in the experiments to be reviewed were adults or high school students, although some studies involved younger children and they will be noted. There is reason to believe that many studies used disproportionate numbers of subjects of high intelligence, ability and motivation. The specific instructional and outcome variables are often poorly defined or peculiar to a particular problem solving situation. Lastly, the studies to be reviewed largely involve short-term lab studies rather than larger, more long-term field studies in actual classroom situations (for reviews of field studies see Coop and Brown, 1970; Della-Piana, 1965).

The existing experimental literature regarding instructional methods can be criticized not only for its problems with extrapolation of results, but also for its problems with inadequate statistical analysis -- a flaw often criticized in the literature, such as Melton's (1941) attack on

Katona's (1940) work or Olson's (1965) questioning of Haslerud and Meyers' (1958) experiment.

By developing a reliable procedure, and defining the various levels of the three experimental dimensions, the instructional method problem becomes: What is the relationship among instructional method, internal activity, and outcome performance? In the review that follows, an attempt will be made to summarize the findings with respect to each of the externally definable instructional variables and subsequent performance measures. In addition, an attempt will be made to suggest what internal cognitive activities or sets may be evoked by the various instructional methods and how these intervening activities relate to learning outcomes.

The Research

Amount and type of direction, internal activity, and performance: Because there is a pervasive lack of coordination among studies of instructional method as to the defining and naming of methods of instruction, many problems can arise simply from semantic disagreements. For example, what one author calls "directed" teaching (Craig, 1956) another calls "intermediate direction" (Kittell, 1957); what one author describes as "discovery" teaching (Bruner, 1961) includes what others call "guided discovery" (Gagné & Brown, 1961), "expository" teaching (Roughead & Scandura, 1968), or "reception" teaching (Ausubel, 1961).

Such difficulties could be minimized if standard definitions based on a single external dimension, e.g., amount of direction, were applied across all relevant studies. A summary of such studies reveals that there seems to be, at least, three general levels of the amount and type of direction: (1) minimum direction in which S receives representative examples to solve on his own, (2) method direction in which S receives

representative examples plus some hint or direction as to the method or principle required to generate the answer, and (3) answer direction in which the final answer is explicitly given to S for representative examples. A fourth level with method direction and answer direction is also possible, though seldom tested.

The earliest lab studies in this area tended to involve human problem solving situations as subject matter. For example, in 1932, Ewert and Lambert published a study in which Ss were taught to solve the three circle problem (as described earlier) using four different methods. Beginning with three discs, subjects solved the problem to a criterion of two correct, then E added a disc and S again worked until correctly solving the problem twice; and this procedure was repeated until S finished the problem using eight discs.

The methods of instruction, ordered in terms of low to high amount of direction, were (1) present problem without any hints, (2) present problems and ask S to look for a general principle, (3) present problem and tell S the general principle (as described earlier), and (4) present problem, tell S general principle, and provide demonstration of the principle. The first two methods could probably be classified as minimum direction methods, while the last two methods seem to provide method direction.

As a performance measure, Ewert and Lambert used a sort of savings on transfer measure by comparing the difficulty in solving the 4, 5, 6, 7, and 8 disc problems for the four instructional groups, as shown in Table 1. Ewert and Lambert concluded that increased instruction decreased average number of trials, excess moves, and time in transfer learning.

It appears that providing S with the required problem-solving principle in general, saved time and effort in learning to solve the

TABLE 1

Performance on Transfer Problems by Instructional Group

(Data from Ewert and Lambert, 1932)

Instructional Group	Average Total Trials	Average Excess Moves	Average Total Time (sec)
1	44.2	1154.6	8502.4
2	42.4	757.9	6220.2
3	15.1	300.8	2435.1
4	16.3	304.6	2481.8

problems to which it applied. The generality of this fact is limited by the nature of the task, a very difficult one; in other words, statement of the general principle involved may increase learning and transfer efficiency only in situations in which S would not otherwise discover the principle. In the present case, the inability of Group 1 and Group 2 Ss to verbalize the solution principle suggests that "learning by discovery" Ss may simply have never come in contact with the to-be-learned content material. It also seems that the problem is of sufficient complexity that the act of trying to apply the principle requires some active search and retrieval processing on the part of the subject; hence, Group 3 and 4 learning may involve a "meaningful learning set" as well as obviously satisfying the "content conditions" (Ausubel, 1961).

Evidence that it is not minimum direction per se that produces poor learning but rather a failure to come in contact with the required to-be-learned content, is provided by Gagné and Smith's (1962) finding that Ss given no direction but who could verbalize the correct solution principle (and hence had discovered the required content) demonstrated the same transfer advantages as Ewert and Lambert's Group 3 and 4 Ss.

The Luchins work (Luchins, 1942; Luchins & Luchins, 1950) provides another classical indication of the detrimental effects of minimum direction: not an inability to come in contact with a solution principle as in the Ewert-Lambert study, but rather a failure to develop a solution principle of sufficient breadth and generality. The Luchins "jar problem" involves presenting S with the hypothetical situation of having three jars of varying sizes as well as an unlimited water supply, and asking S to figure out how to obtain a required amount of water. The problems, in order of presentation, are reproduced in Table 2.

TABLE 2
The Luchins Jar Problems
(From Luchins, 1942)

Problem	Given Jars of the Following Sizes			Obtain the Amount
	A	B	C	
1.	29	3		20
2. E1	21	127	3	100
3. E2	14	163	25	99
4. E3	18	43	10	5
5. E4	9	42	6	21
6. E5	20	59	4	31
7. C1	23	49	3	20
8. C2	15	39	3	18
9.	28	76	3	25
10. C3	18	48	4	22
11. C4	14	36	8	6

Subjects in the experimental group solved the problems E1 through E5 by discovery, being given no direction other than a statement of the problem and the constraints. Luchins found that Ss in this group seemed to learn the solution principle $B - A - 2C$ quite well; however, on problems

C1 through C4 which constitute a sort of transfer task, experimental Ss continued to apply the B-A-2C rule even though more direct solutions were possible. Control Ss who began with problem C1 showed a much higher percentage of these direct solutions than did experimental Ss.

One interpretation is that on easier tasks such as this one, minimum direction may fail to allow S to come in contact with solution rules of satisfactory generality. In the present case, even torpedoing procedures (Davis, 1958, 1966; Bruner, 1963) such as problem 9 which is not solvable by the B-A-2C rule, having S write "Don't be blind," or limiting the amount of water available often fail to broaden the discovered rule.

Katona (1940) provided another set of problem solving situations, namely "card tricks" and "matchstick problems." A typical card trick problem involves figuring out how to arrange eight cards such that if S deals the top card face up on the table, puts the next card on the bottom of the deck without determining what it is, places the third card face up on the table, puts the following undetermined card on the bottom, and so on until all cards are dealt, the cards put on the table follow the sequence: red, black, red, black, red, black, red, black.

The problem solution is taught by two methods: (1) "learning by memorizing," an answer direction procedure in which the specific order of the deck (i.e., RRBRRBBB) required for solution is given to S in its entirety for S to memorize, and (2) "learning by understanding," a method direction procedure in which E provides a system -- the "diagram method" -- for going about solving the problem. The system is to write down the required color for each card for each run through the deck as is shown below:

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Beginning	?	?	?	?	?	?	?	?
First Run	R	?	B	?	R	?	B	?
Second Run		R		?		B		?
Third Run				R				B
Required Order	R	R	B	R	R	B	B	B

In one experiment subjects in the memorization group learned task 3 (presented above) and task 4 (by dealing out every other card produce the chain of spades from ace to eight) by memorizing the required deck order for four minutes while Ss in the understanding group had the same time to learn, by means of the suggested diagram, how to arrange the deck for task 3 only. A control group received no training. An immediate transfer task consisted of the previously learned task (task 3), an easy variation of task 3 (task 1, output BRBKBR by dealing every other card) and a difficult variation (task 2, output same as task 3 dealing every third card); a four-week retention-transfer task consisted of task 3, task 4, and task 5 (same output as task 1 except deal out every third card).

The results are summarized in Table 3 in terms of percent correct with asterisks indicating that S had the task as an example during training.

TABLE 3

Percent Correct on Transfer and Retention Problems
for Two Instructional Groups and Control Group
(Data from Katona, 1940)

Transfer Test	No. 1	No. 2	No. 3
Group Mem (N = 26)	23	8	42*
Group Und (N = 25)	44	40	44*
Group Con (N = 32)	9	3	9
Retention Test	No. 3	No. 4	No. 5
Group Mem (N = 22)	32*	36*	18
Group Und (N = 21)	48*	62	52
Group Con (N = 22)	9	14	9

As can be seen, memorization Ss (Group Mem) performed slightly better on immediate retention but much worse on transfer and long term retention than understanding Ss (Group Und).

Katona also reported studies in which Ss learned to solve "match-stick problems" by several instructional methods. Two of the instructional methods were: (1) Group Mem, an answer direction group in which the complete solution steps were presented to S in order, moving one stick at a time, and repeating six times, and (2) Group Help, a method direction group in which E presented a series of hints by shading in squares that are essential and pointing out sticks to be moved. For example, for the problem below in which S must move three sticks to get four squares (of sides 1 stick wide and 1 stick long), the first method involves showing S the required moves:



The second method involves a series of hints accompanied by "Try to understand what I am doing":



Again, the memory method seems to fit the answer direction classification (giving the answer in final form for representative examples) while the help method reflects method direction (giving methodological hints for solving representative examples).

In a typical experiment, all Ss were given a foretest to assure an initial state of inexperience, practice on two tasks via a given instructional method, and delayed tests (for some Ss after 1 week, for others after 3 weeks) on the learned tasks as well as on the two new transfer tasks. The results, in terms of percent correct, are given in Table 4.

TABLE 4

Percent Correct on Practiced and New Tasks
after One or Three Weeks
for Two Instructional Groups and Control Group
(Data from Katona, 1940)

	Group Mem (N = 26)	Group Mem (N = 28)	Group Help (N = 22)	Group Help (N = 27)	Group Con (N = 30)
Test after 1 week					
Practiced Tasks	67		58		12
New Tasks	25		55		12
Test after 3 weeks					
Practiced Tasks		53		52	12
New Tasks		14		55	12

The Group Mem Ss, who had answer direction, performed quite well, better than the Group Help Ss on retention (both after 1 and 3 weeks) of the solution for practiced tasks; however, Group Help Ss, who received only method direction during learning excelled (as did Group Und Ss with card tricks) on transfer tasks.

In both kinds of studies, answer direction had the effect of aiding retention of the solution for specific examples S learned, while method direction had the effect of aiding transfer to new and different problems. One contradiction to this generalization is the often poor transfer performance of a method direction group Katona labeled Group Arith. These Ss learned to solve representative matchstick problems by E stating the "double function principle" (e.g., when going from 5 to 4 squares "all lines with a double function, that is, limiting two squares at the same time, must be changed into lines with a single function, limiting only one square") and then presenting the solution steps. One reason why Group Arith Ss often performed like Group Mem Ss may be that it was possible for them to memorize the

answer without ever having to understand how to apply the double function principle.

The design, the lack of clear definitions, and particularly, the lack of statistical analysis have been well criticized (see Melton, 1941; Katona, 1942) and to the extent that these criticisms are justified, an interpretation of Katona's results is difficult. However, the detrimental effects of answer direction with respect to transfer performance was established as an important research issue. One possible interpretation of such findings is that overspecification of the correct answers for representative examples, especially for relatively easy problems such as these, reduces the probability of S actively searching for some general strategy and encourages a passive registration of solution sequences -- Ausubel's "rote learning set." Conversely, method direction encourages active memory search in order to interpret E's hints, and apparently also allows S to make contact with the required solution strategy. Just as the Ewert-Lambert and Luchins work pointed to the detrimental effects of minimum direction (perhaps due to S's failure to find the appropriate principle), Katona's work suggests one look for similar detrimental effects of answer direction with respect to transfer (perhaps due to S's failure to encode the content into a broad or meaningful cognitive set).

Some support for this interpretation comes from a study by Corman (1957) in which Katona's matchstick problems were taught using nine methods. In all cases, three representative problems were given with either "no," "some" (a clue to note the number of sticks involved), or "much" (a statement of the principle) information about the "double function principle," and "no," "some" (shading of critical squares), or "much" (indication of sticks to move) information about the method of solution. A transfer test

to both simple (very similar) and complex (different) matchstick problems and a principle verbalization test yielded the result that, on the average, guidance Ss performed better than no guidance Ss. For information about the method, "some" and "much" information produced better transfer than "no" information. For information about the principle, the more information given, the better S could verbalize the principle at the end; however, no consistent effect on transfer was noted.

The "no information" Ss correspond closest to a minimum direction classification, the "some" and "much information" Ss correspond to what was classified as method direction in the Katona experiments, and there was no group fitting the answer direction class such as Katona's "Group Mem." Putting the Corman and Katona results together, method direction (presentation of examples with hints concerning the method of solution) resulted in better transfer than either minimum direction (no hints) or answer direction (specification of exact solution steps) for matchstick problems. Again, however, the fact that presenting the double function principle did not consistently aid transfer in either set of experiments points to the need to better understand how hints influence S.

A series of experiments by Hilgard and his associates (Hilgard, Irvine & Whipple, 1953; Hilgard, Edgren & Irvine, 1954) attempted to analyze more closely the learning behavior of subjects in Katona's card trick problems. In one experiment (Hilgard, Edgren & Irvine, 1954) S was taught to solve two examples using one of five variations of "learning by understanding": (1) Katona's diagram method, (2) same method using only one horizontal row, (3) same method using only one vertical row, (4) same method using blank pieces of paper, (5) working backwards using the actual deck. Although there were no differences among the methods in a

subsequent transfer task except for method S, what did interest the authors was the fact that Ss' errors were related to the type of method used, as if even "learning by understanding" Ss committed errors suggesting a mechanical or rote application of the various "helps."

In comparing a "memorizing" group with an "understanding" group, Hilgard et al. (1953) found that the understanding group took significantly longer than the memorizing group to solve the two practice problems (a mean of 130 and 123 seconds for the memorizing Ss and 435 and 202 seconds for the understanding Ss for the two tasks respectively), performed no differently from memorizing Ss on a 1-day retention test although having had the advantage of twice the practice, and performed significantly better on a set of transfer items (a total of 3, 1 and 1 correct responses from 30 memorizing Ss and a total of 16, 7, and 10 correct from 30 understanding Ss for the three tasks respectively).

Along with this replication of the Katona finding of the superiority of method over answer direction on tests of transfer, Hilgard et al. pointed out that many so-called "understanding" Ss did not really understand the diagramming device in the full sense. In support of Ausubel's (1961) claim, the transfer performance of many of Hilgard's method direction or "understanding" Ss demonstrated that a supposedly meaningful principle (namely, the application of the diagram method) could be learned in a mechanical way. Apparently, although the diagram hints more often than other methods lead to a true, broad understanding in the sense of an ability to relate it successfully to new instances, some "understanding" Ss managed to encode the diagram principle into a "rote" or "low meaningful learning set."

A second major subject area has been teaching S to perform in principle

or concept identification tasks of various types under various instructional methods. Craig's (1956) experiment is the fore-runner of more recent method-of-instruction studies. The procedure was to present the following: pretest, training A (on the first day), training B (on the fifteenth day), training C (on the 29th day), retention test (on the 32nd day), and finally a transfer test. The training involved finding "the word that doesn't belong" in sets of five words. For example, given:

CYCLE SELDOM SAWDUST SAUSAGE CELLAR

the appropriate answer is to mark CYCLE since it doesn't share the same initial sound as the other words. Items were organized in sets of four all having the same relational rule (e.g., initial sound) and each training booklet contained several such types of rules.

Two instructional methods were used: one group -- the "directed group" -- was told the relation (e.g., "look for initial sound") at the beginning of each set of four items but was not told the answer per se, while the other group -- the "independent group" -- was told neither the relational concept nor the correct answer. In this case it seems that it is fairly reasonable to differentiate the groups in terms of amount of direction with the former fitting the method direction and the latter fitting the minimum direction classifications. Directed Ss correctly learned significantly more relations in each of the three training sets than independent Ss and a retention test held on the 32nd day also indicated a clear superiority of the directed over the independent Ss for relearning in all three training sets. Transfer tests yielded no significant differences between the groups.

In short, Craig points out that the directed group -- a group receiving some direction concerning method -- learned more efficiently,

retained better and transferred just as well as the independent group -- a group receiving minimum direction. This study complements the previous findings using other problem solving situations and calls into doubt the emphasis on extreme classroom freedom and independence: Ss may simply not be able to uncover the appropriate concepts or rules without some direction. The fact that independent Ss solved significantly fewer items during training underscores this hypothesis; however, the failure of both groups to reach the same initial criterion of learning makes interpretation of the retention and transfer data more difficult.

The hypothesis to be tested is this: The procedure of giving hints about the principle or method -- but not giving S the exact answer in final form -- encouraged S to actively search and discover how the hints apply to the material. Subjects given no direction may simply never identify the relational concepts and hence have to encode in a piecemeal, item-by-item way just as answer direction Ss are encouraged to ignore rules and rather to encode specific answers. Such an interpretation helps "make sense" out of the findings; however, to correctly test the hypothesis of structurally different learning outcomes, and not just differences in initial learning, a uniform standard of initial learning for all groups is required.

Kittel (1957) reported a study using material similar to Craig's but which involved a better controlled learning criterion, instructional groups representing all three levels of the amount of direction, and a more sophisticated transfer-retention test. The procedure consisted of a pretest, training, and three posttests on the first, fifteenth and 29th days. The training, like Craig's, involved giving S a set of five words, e.g.

GONE START GO STOP COME

and asking S to mark the word that doesn't belong. In the above example,

the relational principle is "form two pairs of opposites" and, hence, the answer is "Gone." In the training booklet each group of three items had the same principle and there were 15 such groups in all.

Three instructional conditions, reflecting varying amounts of direction, were used: (1) Subjects in the "minimum direction" group were told only that each group of three problems had the same underlying principle. (2) Subjects in the "intermediate direction" group were told what the principle was for each group but were not given the specific answer. (3) Subjects in the "maximum direction" group were told both the correct answer and the principle. In comparison to the Craig study, the "minimum direction" group corresponds to Craig's "independent" group, the "intermediate direction" group corresponds to Craig's "directed" group, and the "maximum direction" group represents both method and answer direction, a group omitted from the Craig study.

On the first, 15th, and 29th days Ss were given the original training booklet (without rules or correct answers indicated) as a retention test. Also on the first day, two transfer tests were administered, one involving the principle but with different items (near transfer) and the other involving both new principles and new items (far transfer). The findings, indicating number of principles correctly learned or relearned, are in Table 5.

TABLE 5

Average Number of Correct Items on Retention and Transfer Tests

for Three Instructional Groups

(Data from Kittel, 1957)

	Minimum Direction	Intermediate Direction	Maximum Direction
Immediate Retention	2.6	3.7	3.7
Near Transfer	1.9	4.6	2.9
Far Transfer	1.7	4.6	2.7
Two-Week Retention	1.6	3.5	2.9
Four-Week Retention	1.2	3.3	2.3

As can be seen, the minimum direction group -- as in the Craig study -- apparently learned less, as measured by immediate retention, and performed poorly on retention and transfer tests as compared with the other two groups. However, the intermediate and maximum direction groups reached the same level of initial learning as measured by immediate retention, but differed significantly in their respective transfer and retention tests, thus suggesting more complicated differences in learning outcome.

The suggestion that Ss in the different instructional groups are performing different cognitive acts during learning has been the object of more recent study. Kornreich (1969, p. 384), for example, stated: "Clearly, studies are needed which specify how teaching procedures differ for groups, how these procedures differentially affect S's behavior during learning, and how both teaching procedure and S's studying behavior results in differences in criterion pervormance."

In addition, Kornreich (1969) reported a study involving the relationship between instructional method and S's behavior or "strategy" in a CI task. The problems consisted of four cards, with two stimuli per card, each varying in color (black or white), size (large or small), letter (T or X), and position (right or left), e.g.,



The S was required to point to one stimulus and E responded "right" or "wrong," after which S was required to indicate all possible correct cues. This was repeated for all four cards of each problem, and there were 24 separate problems in all. The optimal strategy involves a "focusing" procedure whereby S reduces the number of alternatives to four after card 1,

to two after card 2, and 1 after card 3, for each 4-card problem.

The instructional methods for learning to solve the 24 problems were: (1) "discovery group" which received no hints, (2) "guided discovery group" which was told after each card whether the procedure S was using was or was not optimal, (3) "programmed" group which was told after each card the appropriate moves to make. The groups correspond to the minimum, method, and answer direction classifications, respectively. Kornreich was mainly interested in S's ability to develop the optimal "focusing strategy" and the results indicate that significantly more of the guided discovery Ss (20 out of 33) acquired the focusing strategy than either discovery Ss (5 out of 33) or programmed Ss (11 out of 33).

Again, as in previous studies, it seems discovery Ss simply fail to discover the required principle or concept while answer direction Ss react to "overprompting" by encoding specific correct responses rather than the solution principle. Kornreich suggests the advantage of the GD group rests in its rereading and thinking about the original instructions; GD subjects not allowed to reread the instructions did not learn the focusing strategy as well (6 out of 20). The emphasis on finding the behavioral effects of amount of direction during learning was summarized by Kornreich (p. 388): "The discovery learning controversy, then, becomes a considered analysis of what educational prompts are optimal for achieving educational goals, rather than an issue over whether discovery or rote learning is better."

Guthrie (1971) reported an experiment in which sixth graders, from both low and high socio-economic status (SES) homes, learned a language concept accompanied by different amounts of S behavior, prompted by different amounts of direction. The concept was: "After the word 'the' K

comes before consonants and T comes before vowels" (e.g., "the K girl scout" or "the T outlaw"). All Ss performed in a vowel-consonant discrimination task to a criterion of 40 correct, and all Ss performed to a criterion of eight correct in a concept formation task consisting of sentences of the form: "That girl was the K girl scout. Change girl scout to outlaw."

In addition, (1) Group 1 Ss memorized the rule as stated above to a criterion of two correct verbalizations, applied the rule to questions about example words or sentences (e.g., What comes before words that begin with vowels?), and produced instances for example words (e.g., given "apron" respond "T apron") to a criterion of 12, (2) Group 2 Ss performed only the first two tasks, (3) Group 3 Ss performed on the first task, (4) Group 4 Ss performed in none of these tasks. Group 4 represents a minimum direction group in that no rule or hint or answer was provided, while the other groups represent varying levels of method direction in that methodological hints are given but specific answers are not.

An analysis of trials to criterion on the concept-formation task for both SES levels indicates a significant effect due to instructional method with better performance for groups that had more directed tasks in learning, as shown in Table 6.

TABLE 6

Average Number of Trials to Criterion
for Four Treatment Groups and Two SES Levels
(Data from Guthrie, 1971)

	Treatments			
	Group 1	Group 2	Group 3	Group 4
Low SES	15.0	21.7	32.6	50.0
High SES	6.5	8.6	21.7	50.0

In a relatively difficult task such as the present one, rule verbalization significantly improved S's performance, and having S apply the rule in response to E's questions also improved savings in subsequent learning. Direction about the solution method which provides both the required rule, and a chance to understand it by trying to apply it in complicated (for children) examples seems to offer advantages in ease of learning over minimum direction methods. However, as in the Kornreich study, little can be said about retention or transfer.

Experiments using decoding tasks offer a more direct test of retention transfer performance. For example, Forgas and Schwartz (1977) taught a 26-symbol alphabet by three instructional methods and recorded measures of ease of learning, retention and transfer. The to-be-learned code was:

A	B	C	F	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Λ	Δ	Δ	Δ	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□

The instructional methods were: (1) "observer group" which was given the code as presented above with a written explanation of the principle, (2) "participant group" which was given the code as presented above and told to look for a verbalize the principle, and (3) "memorization group" which was given the same 26 pairs as above but randomly arranged so that the principle was difficult to find. Assuming the orderly arrangement is enough hint for "participant" Ss to recognize the rule, the first two groups are method direction methods which enable S to encode a general principle or strategy while the final group is -- like other minimum direction, discovery methods -- forced to encode the material in a specific, item-by-item manner. This interpretation of what S is doing during learning is consistent with the fact that

"memorization" Ss took twice as long to reach a criterion of learning as Ss in each of the other groups.

One week later, E administered a recall test requiring S to translate a passage from the learned code into English, a near transfer test requiring S to translate a passage from a slightly modified code (S is given $A = \wedge$, $F = \square$, $J = \boxtimes$, $T = \odot$, $Z = \int$, and must generate the rest) into English, and a far transfer task requiring S to translate a passage from a very different code (S is given $A = 11$, $B = 12$, $C = 13$, $D = 14$, $E = 21$, $F = 22$, $G = 23$, $H = 24$, $I = 31$... $Z = 62$, and must generate the rest) into English. The number of words correctly translated, out of a possible total 52, for each group on each task is indicated in Table 7.

TABLE 7
Average Number of Words Correctly Translated
on Recall and Transfer Tests
for Three Instructional Groups
(Data from Forgas and Schwartz, 1957)

	Recall	Near Transfer	Far Transfer
Observer Group	50	30	34
Participant Group	52	31	37
Memorization Group	37	11	10

As can be seen, the first two groups not only learned significantly faster but also retained more and transferred better than the third group. The fact that there was no difference between observer Ss who were given the rule (but presumably had to try to understand how to apply it) and participant Ss who were given hints as to the rule (namely, the orderly arrangement) suggests the task was simple enough for the latter group to

find the rule and that both groups encoded the rule in a similar manner.

Some support and an apparent contradiction to this finding of an overall inferiority of minimum direction Ss is reflected in Haslerud and Meyers' (1958) data. Subjects were given 20 coding problems, half with the decoding rule given ("guided method") and half with no direction given ("discovery method"). In tests of initial learning it was found that Ss learned significantly fewer items by discovery than when provided intermediate direction. However, in a transfer test held one week later in which the same 20 decoding principles were applied to 20 new sentences, performance on the discovery-taught principles equalled performance on principles taught with method direction.

Because transfer performance improved on discovered principles and fell on guided principles relative to initial learning, Haslerud and Meyers claimed that minimum direction results in superior delayed transfer. This faulty interpretation based on difference scores rather than absolute transfer scores ignores the fact that there was no difference between the groups in absolute transfer performance (Olson, 1965). Another problem in interpreting anything more than ease of learning measures is that, due to the within-subject design, it is not clear that learning 10 items by the guided method did not transfer to the 10 discovery principles.

In a better controlled "decoding" experiment, Wittrock (1963) taught Ss to decipher cryptograms using four instructional methods and assessed learning outcomes in tests of learning ease, retention and transfer. The task involved deciphering a series of 10 sentences such as HRNTME DTGEON RKPAHE (Answer: MEN THROGDED THE PARK under the rule "exchange the first two and last two letters in each group"). The first page of each problem presented the rule or left room for it to be derived; page 2 contained an example enciphered

sentence with either a space or the deciphered sentence below; and page 3 contained an enciphered sentence based on the same rule for S to try (as a learning test).

The instructional methods were: (1) rule given, answer given (containing elements of both method and answer direction), (2) rule given, no answer given (a method direction group), (3) rule not given, answer given (answer direction), and (4) rule not given, answer not given (minimum direction). Three weeks after learning, a retention test (same principles, same examples), a near transfer test (same principles, new examples), and a far transfer test (new principles, new examples) were given. The average number correct out of 10 for each group is given in Table 8.

TABLE 8

Average Number of Correct Items on Retention and Transfer Tests
for Four Instructional Groups

(Data from Wittrock, 1963)

	Learning Test		Three Week Retention-Transfer Test		
	No. Learned	Time	Retention	Near-Transfer	Far-Transfer
Rule-No Answer	9.7	51	5.8	4.9	4.0
Rule-Answer	9.5	47	5.3	4.2	3.2
No Rule-Answer	7.6	67	5.3	4.0	3.6
No Rule-No Answer	2.8	104	4.1	3.7	3.0

Presenting the rule and encouraging S to actively figure out just how to apply it in order to derive the correct answer, again, resulted in superior learning, retention and transfer as compared with groups given either no direction or given an exact specification of the answer. Wittrock concluded (p. 189): "When the criterion is initial learning of a few responses, explicit and detailed direction seems to be most effective and efficient.

When the criteria are retention and transfer, some intermediate amount of direction seems to produce the best results."

An experiment by Guthrie (1967) in which Ss learned to decipher cryptograms, demonstrated that when minimum direction Ss (given representative examples without rules or hints) were forced to learn to a criterion equal to that of groups given the rule, they took longer to learn and retained less but transferred better in some cases. Apparently, if minimum direction Ss do learn the decoding principle they are able to transfer quite well; and if rule-given Ss are able to memorize simple procedures rather than develop general decoding techniques, they excel only in learning ease and short-term retention.

Another major subject area has been learning to solve mathematical problems. Gagné and Brown (1961) taught Ss how to calculate series sums and derive formulae (e.g., sum of 1,3,5 7,9, __, __,...) using three programmed instructional methods. In order of minimum, method and answer direction they are: (1) "discovery" which asks S to find the sums of representative series but provides hints if S cannot, (2) "guided discovery" which presents a systematic succession of questions to aid S in solving representative series sum problems, and (3) "rule and example" which gives S the series sum formula and applies it to examples for S. All Ss were required to achieve a criterion of correct solutions for the same four series, thus the possibility of "discovery" Ss not learning was eliminated. The hints provided the discovery group seem to make it, like the GD group, more representative of the method direction classification, while RE Ss better fit the answer direction category.

Subjects were trained on days 1 and 2, and also on day 2 were tested for transfer in a set of series problems. The average time (in seconds)

and errors to criterion learning, and the average time and number of hints requested in transfer are reported in Table 9.

TABLE 9
Average Time in Seconds and Number of Errors
on Initial Learning, Relearning and Transfer
for Three Instructional Groups
(Data from Gagné and Brown, 1961)

	RE Group	GD Group	Discovery Group
First Learning Time (Errors)	26 (6)	33 (10)	18 (4)
Second Learning Time (Errors)	15 (3)	23 (7)	10 (2)
Transfer Time (Errors)	27 (6.5)	17 (1.5)	20 (2.2)

As can be seen, guided discovery Ss took longest to learn and made the most errors in learning but transfer best; there may be reason to believe that these Ss were more active in terms of cognitive search processes in learning than the other groups, especially the RE group.

In a carefully controlled replication using only GD and RE methods, a clear superiority for GD Ss on immediate and delayed transfer was again demonstrated (Della-Piana, 1965). Della-Piana also reported that Ss who verbalized the solution formula did significantly better on transfer tasks. In contrast to the Gagné-Brown emphasis on "what is learned," Della-Piana argued that "the present findings suggest 'how something is taught' does have an impact on learning."

On this issue, Roughhead and Scandura (1968) provide evidence that "what is learned" by the GD method can also be taught by other methods. An

"expository" program (which presented the same hints as the "guided" program but as statements instead of as questions) coupled with a "rule" program (giving the specific formula and how to apply it) produced the same kind of performance as "guided" methods coupled with "rule" methods on tests of learning ease and transfer. Apparently, as long as the hints about principle or method are given it doesn't matter if they are presented as questions or as statements.

It was found, however, that groups given the rule and how to apply it (answer direction) without any expository or guided frames (method direction encouraging active cognitive search) performed significantly better in learning ease and worse on transfer than groups exposed to less direction. Even when "rule" frames were followed by a chance for undirected "discovery" of the just learned rule, Ss apparently were satisfied to retain the correct answer without trying to develop a higher level derivation rule to explain why.

As a complement to the findings concerning the relative merits of GD-type methods (method direction) and RE-type methods (answer direction), Kersh (1958, 1962) provided some information about minimum and method direction methods for teaching series sums. One to-be-taught principle was the "odd-number rule," the fact that $\Sigma(1 + 3 + 5 + 7 \dots) = N^2$. The minimum direction group, called "no help," received representative problems with no direction, while other groups received either "direct reference" using perceptual aids or "rule giver" treatment asking S to apply the rule to examples. Examples of these latter, method direction procedures, are indicated below:

$$\Sigma(1 + 3 + 5 + 7 + \dots) = N^2 \quad \text{Thus} \quad \Sigma(1 + 3 + 5 + 7) = \underline{4^2} = \underline{16}$$

X	1	4
X > X	3	4
X X X X X	5	4
X X X X X X X X	7	4
	16	16

All subjects were forced to learn to a criterion of three correct solutions and verbalization of the rule, hence the usual prospect of minimum direction Ss not learning was eliminated. Under these conditions all groups performed perfectly on an immediate retention-transfer test and differences on a four week transfer test and questionnaire favored the "no help" (minimum direction) group. A questionnaire indicated that this latter finding could be attributed to higher motivation and practice of the no-help Ss rather than differences in the meaningfulness of the encoding process. However, as in other studies where a criterion of learning was enforced, minimum direction Ss seem able to learn in a manner like method direction Ss. In sum (Kersh, 1958, p. 282): "If meaningful learning is the key concept it should make no difference whether learning occurs with or without direction so long as the learner becomes cognizant of the essential relationships."

In a further study (Kersh, 1962), however, heavily directed Ss (given examples with complete explanations) performed significantly worse on tests of retention and transfer than groups given no explanation or only hints in finding the explanation. As Kersh (1958, p. 282) pointed out: although different methods can produce the same learning set hence the same outcome, "it is very likely that some procedures of learning may be superior to others because they are more likely to cause the learner to become cognizant of the relationship." When a criterion of learning is enforced, it appears that although minimum and method direction Ss may encode in the same way, answer direction Ss may use an entirely different procedure.

An experiment by Gagné, Mayor, Garsters and Paradise (1962), using several variations of the method direction method, supported the claim

that different methods of instruction enforced to a uniform criterion of learning can produce the same kind of learning outcome.. In learning programs for several mathematical tasks, neither differences in the amount of repetition (i.e., two vs. four example problems per idea) nor the amount of guidance (i.e., presence or absence of integrating frames) produced a major influence on retention or transfer performance.

However, the standard finding of detrimental effects on long-term retention and transfer for extreme amounts of answer direction was substantiated by a study by Ray (1961) in which Ss learned to use a precise measuring instrument by two instructional methods. There were no differences between Ss who learned by "direct and detailed instruction" and those who learned by "guided discovery" on tests of immediate and one week retention; however, the guided discovery Ss -- who received less direction about answers -- performed significantly better on a six week retention and transfer test.

A definitive statement on the effects of minimum, method, and answer direction on learning ease, retention and transfer performance is not yet possible; however, on the basis of the current literature, several generalizations can be posited for further study: (1) As compared with the other instructional methods, minimum direction procedures require more learning time and effort and result in lower levels of initial learning, inferior retention and transfer, and inability to verbalize the required principle. However, when the to-be-learned principle is obvious or when a strict criterion of initial learning is enforced, minimum direction Ss are apt to exhibit outcome performance comparable to method direction Ss. (2) As compared with answer direction methods, method direction procedures require more or less learning time and effort depending on the task,

and result in equivalent levels of initial learning, equivalent or inferior short-term retention, superior long-term retention, superior transfer, and ability to verbalize the required principle. (3) In contrast, answer direction procedures require more or less learning time and effort depending on the task, and result in equivalent levels of initial learning, equivalent or superior short-term retention, inferior long-term retention, inferior transfer, and inability to verbalize the required principle.

Although there have been few direct tests of subject activity during learning, the following generalizations constitute worthy research issues for further studies: (1) Minimum direction Ss are actively searching, or as one research group (Anastasiow, Bibley, Leonhardt & Borish, 1970) puts it, "cognitively involved," thus satisfying the "set conditions" (Ausubel, 1961), but often fail to satisfy the "content condition" of coming into contact with the to-be-learned rule or concept. Lacking a unifying principle, material must be coded in an individual, rote answer-by-answer manner, or, as is often the case, not encoded at all. However, when minimum direction Ss do find the required rule or concept, the subsequent learning outcome is similar to that produced under method direction. (2) Method direction Ss are actively searching for how to apply a given complex rule or how to use a given hint, thus satisfying the "set conditions," and have sufficient direction to come into contact with the to-be-learned rule or concept thus satisfying the "content conditions." Therefore, the learning outcome can be characterized, not as a discrete set of individual responses, but as a general rule or what Roughead and Scandura (1968) have called a "derivation rule." (3) Answer direction Ss seem to often lack the "set condition" of active search, being uninterested in why the specific answers given by E are correct, and striving (like minimum direction Ss

but for different reasons) to encode a discrete chain of specific responses.

Of course, there are obvious contradictions to several of these propositions as there are to most temporary generalizations; however, a more definitive analysis of the effect of amount and type of direction on learning requires more information concerning these propositions. One particularly important task is to better define what constitutes "method direction" and thus what types of rules or hints best satisfy the "content condition" without destroying "set conditions."

Sequencing of direction, internal activity, and performance: A second major dimension of instructional method is the sequencing or ordering of direction, and one aspect of sequencing that has produced significant differences in outcome performance is inductive vs. deductive sequencing of direction. As early as 1913, Winch presented evidence demonstrating the superiority of deductive over inductive methods for short-term retention performance, and the superiority of inductive over deductive methods for certain types of transfer performance. In a literature review covering the subsequent half century, Hermann(1969) concluded that there still is qualified support for the claim.

For example, in a well controlled classroom study, Worthen (1968) used two methods to teach children such concepts as notation, addition and multiplication of integers, the distributive principle of multiplication over addition, and exponential multiplication and division. The "discovery" method involved presentation of examples for S to solve followed by verbalization of the required principle or concept (i.e., an inductive sequence) while the "expository" method began with verbalization of the required concept or principle followed by examples for S to solve (i.e., a deductive sequencing).

Significant effects due to instructional method were found in measures

of learning ease (inductive inferior to deductive), long-term retention (inductive superior to deductive) and transfer (inductive superior to deductive) with no differences in subject attitude found. However, a subsequent argument concerning Worthen's statistical analysis -- contending that df's ought to be determined by the number of classrooms rather than the number of Ss in the groups -- has reduced the impact of these findings (Worthen & Collins, 1971). One hypothesis proposed to interpret such results assuming they can be substantiated is that the period of search before rule verbalization, or what Hendrix (1947, 1961) called "nonverbalized awareness," enables inductive Ss to actively encode the to-be-learned strategy or concept into a wider or more meaningful cognitive set, whereas the presentation of the rule -- especially a simple rule -- in advance may predispose deductive Ss toward encoding an isolated series of mechanical steps.

Two similar methods for teaching Ss to decipher "cryptograms" were part of a well controlled laboratory study by Guthrie (1967). The deductive "rule-example" method involved presenting the deciphering rule (e.g., "exchange the first and last letter") followed by examples for S to solve to a criterion of eight correct while the inductive "example-rule" method called for presenting examples for S to solve to criterion followed by a statement of the correct deciphering rule. The performance of the two groups on initial learning, retention (new words, same rules), near transfer (new words, similar rules) and far transfer (new words, different rules) is presented in Table 10. Analyses revealed the advantage of deductive over inductive training for ease of learning and the advantage of inductive over deductive training for near transfer to be at statistically significant levels.

TABLE 10

Performance on Learning, Retention and Transfer
for Two Instructional Groups
(Data from Guthrie, 1967)

	<u>Learning</u> Average Trials to Criterion	<u>Retention</u> Average Number Correct	<u>Near Transfer</u> Average Number Correct	<u>Far Transfer</u> Average Number Correct
Rule-Example	11.9	8.1	4.8	4.1
Example-Rule	23.6	7.0	7.2	5.7

The previously cited Roughead and Scandura (1968) study also supplies some information about the role of sequencing in teaching Ss series summation. Of the seven treatments reported, two seem to fit the general deductive-inductive categories, namely: (1) "rule-discovery" Ss received three series examples with the rules for solution given followed by three series examples to be solved by S using the same rule, and (2) "discovery-rule" Ss received the reverse ordering of three to-be-solved series examples followed by three more with the rule given for each. Measures of initial learning, near transfer (same rules, different numbers) and far transfer (different rules, different numbers) are summarized in Table 11.

TABLE 11

Performance on Learning and Transfer
for Two Instructional Groups
(Data from Roughead and Scandura, 1968)

	<u>Learning</u>			<u>Near Transfer</u>		<u>Far Transfer</u>	
	Average Time (min.)	Average Errors	Average Number Correct	Average Time (min.)	Average Hints	Average Time (min.)	Average Hints
Rule-Discovery	29	1.2	5.5	6.0	1.7	5.9	1.6
Discovery-Rule	33	1.5	5.5	4.4	0.8	5.5	1.2

Again, deductive Ss learned faster but transferred significantly worse than inductive Ss. Roughead and Scandura interpreted such results as indications that in some cases (especially with easy rules) prior knowledge of the solution rule interferes with S's development of a "higher order derivation rule" by encouraging S to memorize specific correct steps without trying to understand why they are correct.

This interpretation squares nicely with much of the text-based (non-problem solving) CAI literature reviewed in recent studies by Anderson, Kulhavy and Andre (1971) and by Sturges (1972). Those studies revealed that giving S knowledge of the correct response (KCR) after S responds to example questions results in significantly better transfer performance than giving KCR before examples. Other non-problem solving studies demonstrating a relationship between poor transfer and heavy prompting on questions during learning (Kress & Gropper, 1966; Anderson, Faust & Rodenick, 1968), very specific questions during learning (Watts & Anderson, 1971) and placing questions before rather than after relevant material (Fraser, 1967; Rothkopf & Bisibicos, 1966) also square with this interpretation.

Another problem-solving study (Mayer & Greeno, 1972) attempted to vary sequencing in a programmed text for the concept of binomial probability (i.e., the probability of obtaining R successes in N Bernoulli trials) in the following manner: (1) Group G Ss "began by learning about component variables of the formula (e.g., the concepts of 'trial,' 'success,' 'probability of success,' etc.) and gradually learned to put them together" while, (2) Group F Ss "were first introduced to the complete formula and then gradually learned how the component variables figured in using the formula" (p. 166).

Although the Mayer-Greeno instructional methods fail to fit the inductive-deductive classifications as well as previous studies, it seems that the Group F rule-to-application sequence and the Group C application-to-rule sequence reflect overall deductive and inductive teaching strategies, respectively. Summarized in Table 12 are the typical results of a subsequent transfer test composed of problems requiring a direct "plug-in" into the formula rule (Type F), problems requiring a minor algebraic transformation before "plugging in" (Type T), problems that were not answerable (Type U), and questions about the formula (Type Q).

TABLE 12
Proportion Correct by Question Type
for Two Instructional Groups
(Data from Mayer and Greeno, 1972)

	Type F	Type T	Type U	Type Q
Group F	.75	.57	.43	.43
Group C	.48	.40	.63	.83

Significant interactions in transfer performance like that above were found in three cases suggesting that the two instructional methods produced "structurally different learning outcomes" -- one supporting good near transfer but poor far transfer and one supporting poor near transfer but good far transfer. This interaction was essentially eliminated when Ss in both groups were required to answer many questions during learning, thus suggesting that: "by having subjects in both groups focus their attention on finding the answers to specific questions, apparently there was such similarity in their mathemagenic (Rothkopf, 1970) behavior that the differences in sequence of presentation failed to produce a substantial dif-

ference in learning outcome" (p. 173).

Apparently, the type of task may influence the effects of sequencing. In the Worthen, Guthrie and Roughead and Scandura experiments, deductive Ss excelled in learning ease but inductive Ss excelled in near and far transfer; but in the Mayer and Greeno study deductive Ss excelled on near transfer and inductive Ss excelled on far transfer. In other words, on some tasks, where only one specific complex rule or algorithm is learned, deductive training may result in superior near transfer (i.e., direct application of the rule) as well as initial learning ease.

Evidence for the advantage of deductive instruction on ease of initial learning and on use of specific rule application procedures (near transfer) is complemented by a recent study (Deno, Jenkins, & Massey, 1971) in which Ss learned to classify EKG patterns by two methods. (1) The "deductive" group was given an explanation of the classification rules followed by representative examples for S to classify to a criterion of five in a row, while (2) the "inductive" group was given representative examples for S to classify to a criterion of five in a row followed by, it was assumed, S's understanding of the rule.

On a subsequent transfer test using 30 photocopies of actual EKG patterns, deductive Ss correctly classified significantly more patterns (22.9 on the average) than inductive Ss (19.1 on the average). The authors concluded that deductive training better prepares S to apply a standard classification rule in a complex situation. Performance on more remote transfer tasks was not assessed.

The importance of the general rule or principle and its role in S's encoding of material is highlighted in a series of studies by Katona (1942b) in which he varied the presentation order of A-texts which explained a given

rule or principle (e.g., in the figure , angle A + angle B + angle X = 180 degrees) and B-texts which presented some facts for S to remember (e.g., the dimensions of a plot of real estate shaped ). The results indicate that it is often easier to remember the facts in the B-text if the A-text precedes it rather than follows. In this case, as in the EKG classification study, pre-familiarization with the rule provided an economical organizing principle for the required task. Apparently, if application of the stated rule is the objective, deductive instruction is most effective; and if more sophisticated transfer is the objective, inductive instruction is superior.

In another study an attempt to teach algebra by inductive ("applications or examples of a yet unstated definition or principle followed by the discovery and statement of the definition or principle") and deductive ("statement of rule or definition followed by examples or applications") programs yielded significantly different immediate retention performance in favor of the deductive group but failed to find significant differences in the ability to transfer the learned concepts (Belcastro, 1966). Although this study replicates the finding of an advantage in ease of learning for deductive Ss, it is difficult to interpret the transfer data due to a failure of the two groups to reach equal levels of initial learning.

Similarly, Nelson and Frayer (1972) have reported a study in which geometry concepts (quadrilateral, parallelogram, trapezoid, and rhombus) were taught to sixth graders by two different kinds of written lessons. (1) The "discovery" method was inductive in that questions about definitions or defining properties were asked after each example set, while (2) the "expository" method fits the deductive classification because

statements of definition or defining properties came before representative figures.

For example, "discovery" Ss received a figure followed by a line of questioning. "Look at this figure. Measure side AB. Measure side AC. What do you find? How is this like the figure in the last question?" In the "expository" lessons, on the other hand, each example was preceded by statements such as: "Look at this figure. This figure is a trapezoid. Note that side AB is parallel to side AC."

Using independent groups, Nelson and Frayer found an overall superiority of expository over discovery group performance on immediate, 1-day, and 21-day retention and both groups performed significantly better than a control group which received no relevant instructions. A repeated measure analysis of data summarized in Table 13 yielded a significant change in performance between the groups over the retention interval; however, it must be noted that, again, on both tests expository Ss scored higher. In addition, Nelson and Frayer reported that, on the average, expository Ss took 15 minutes to learn as compared with 50 minutes for discovery Ss.

TABLE 13

Average Number Correct on Retention Tests
for Two Instructional Groups and Control Group
(Data from Nelson and Frayer, 1972)

	1-Day Retention Test	21-Day Retention Test
Expository	18.2	15.8
Discovery	14.7	15.0
Control	11.5	12.1

Two problems with generalizing these advantages of deductive training is that no criterion of initial learning was enforced and no transfer test was used. Another difficulty is that Scott's (1970) results, using the same materials and a repeated measures design, directly contradict these findings. On a test of immediate retention no significant differences between the groups was found; however, on a 21-day retention-transfer task set, discovery Ss significantly outperformed expository Ss. The fact that the Nelson-Frayer groups differed on immediate retention but the Scott groups did not may be due to differences in criterion learning; if this is the case, the Nelson-Frayer findings may be interpreted as reflecting quantitative differences in amount learned while the Scott findings reflect qualitative differences in encoding. Future research incorporating learning criteria and transfer tests as well as measures of learning difficulty and retention must resolve this matter.

A further confirmation of the reported advantage of deductive Ss on ease of learning measures is offered by Koran (1971). Subjects were taught elementary statistical concepts (e.g., mean, median, normal curve) via instructional programs that either (1) presented rule frames (stating definitions or principles) before example frames (offering application opportunities for S), or (2) presented example frames before rule frames. Although the difference in average learning time (81.5 minutes for deductive Ss and 82.9 minutes for inductive Ss) did not reach statistically significant levels, deductive Ss made significantly fewer errors (an average of 10.4) than inductive Ss (an average of 13.8) during learning.

On a test given two weeks later that involved both retention (asking S to state previously learned rules or concepts from cues) and transfer (asking S to apply them to previously unencountered problems), there was not

a significant difference between the groups. However, since Koran failed to separate performance from transfer performance, there is no way of testing the proposition that deductive Ss excell on retention and inductive Ss excell on transfer.

A more serious non-confirmation of differences between instructional methods comes from an experiment on teaching physics concepts (e.g., inertia, mass, weight, force, and moment of inertia) conducted by Maltzman, Eisman and Brooks (1956). The "traditional" method of instruction, following a deductive tack, presented S with a physics text followed by an illustration of the moment of inertia concept using a torsion pendulum (E demonstrated that the pendulum moved faster when weights were closer to the center of gravity); the "modern" method, following an inductive sequencing, presented S with the torsion pendulum as a problem (E asked S to figure out how weight placement related to speed of swing) followed by the physics text.

On a retention test of the material in the text, there was no significant difference between the groups. On a transfer task S was asked to solve the "two-sphere" problem: given two spheres of equal weight and size but made of different metals such that one is solid and one is hollow, how can they be differentiated without using any special equipment or damage. The correct answer, obtainable from the text concepts, is that they would roll at different rates down a slope and was given equally often by Ss in both groups (50% for each).

In comparison with previous studies, Maltzman et al.'s experiment employed an entirely different subject area and more conventional material. As Koran (1971) has pointed out, there is some support (Krumboltz & Yabroff, 1965; Wolfe, 1963) for the notion that sequencing has its greatest influence

on teaching "puzzle-type" tasks, and the method is less important for conventional text-lecture materials. The presentation of this possibility, however, is not accompanied by any theoretical explanation; nor is it clear that the fact has been established. For example, in an earlier study using basically the same procedure as Maltzman et al., Szekely (1950) found the "modern" method Ss performed significantly better than "traditional" method Ss on the two-sphere problem (an average of 65% and 20% correct solutions, respectively).

In summary, due to the fairly small, hard to interpret, and not completely consistent experimental data base concerning rule-based material, any generalizations about the effects of deductive vs. inductive methods on learning ease, retention and transfer remain to be tested. The present level of research findings does suggest that the following generalizations, based on type of material taught, should be among those given careful consideration: (1) For teaching a set of simple solution rules, all related to a sort of general or intuitive problem solving strategy (e.g., Guthrie's cryptograms), deductive methods result in superior learning ease and retention but inductive methods result in superior near and far transfer. (2) For teaching a single, complex, non-intuitive algorithm (e.g., Deno et al.'s EKG pattern classes), deductive methods result in superior learning ease, retention and near transfer but inductive methods result in superior far transfer.

A careful analysis of internal activity during learning should test the propositions that: (1) Deductive Ss, being given the to-be-learned rule, see their task as being able to apply the rule to examples like those shown or thus encode the rule within a fairly narrow cognitive set emphasizing mechanical operations. (2) Inductive Ss see their task as being

able to generate rules for various examples, and hence encode the material into a broader cognitive set emphasizing the general properties of the concepts involved.

Some information about the effect of encouraging S to encode the to-be-learned concepts more broadly is provided by a recent study (Gagné & Bassler, 1963) demonstrating that sixth graders who learned geometry concepts accompanied by a narrow range of examples performed significantly worse on long-term retention than Ss receiving no examples beyond those in the program. Apparently, the presentation of a narrow range of examples, although giving Ss more practice, either encouraged Ss to encode in a different or in a weaker way than other Ss.

Structuring of direction, internal activity and performance: A third dimension of instructional methodology also involves sequencing. But rather than investigating the effects of placing a statement of the to-be-learned rule before or after representative examples, this dimension deals with how the rule or concept is explained -- in a smooth, systematic, hierarchical manner eliciting few errors during learning (as proposed by Skinner, 1958, 1965; Gagné, 1962, 1963, 1968) or in a discontinuous, unstructured manner eliciting far more errors (as proposed by Pressy, 1967; Bruner, 1963). Skinner (1958, p. 974), representing the traditional reinforcement theory or "programmed learning" position, offers the to-be-tested proposition as follows: "...facts, terms, laws, principles, and cases ... must then be arranged in a plausible developmental order...."

Many of the studies dealing with systematic or error-minimization methods vs. discontinuous or error-elicitation methods have developed out of the context of programmed, teaching machine and, more recently, computer assisted instruction. Due to the enormous breadth of this area

and its traditional emphasis on verbal, text-type learning and retention (Skinner, 1958), the present review will be limited to one well-tested instructional variable and its relation to principle-based or problem solving material. A major test of the structured-unstructured question (or as some have put it, the small step - large step question) has taken the form of "scramble studies"; experiments dealing with the effect of randomizing the presentation order of some unit (e.g., frames, paragraphs, etc.) of the instructional material, hence increasing the difference among adjacent units and the possibility of subject error.

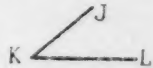
An early study by Roe, Case and Roe (1962) using a "guided discovery" type program for teaching statistics revealed no significant difference in errors in learning or post-test retention-transfer performance between scrambled and normal order groups. This finding was replicated by Levin and Baker (1963) using a geometry program (e.g., dots, lines, angles, triangles) for second graders; there were no significant differences in median errors to learn, time to learn, retention or transfer among Ss who received the 180-frame program in normal order and those who received the program with the 60-frame "angle" section -- deemed the hardest -- in scrambled order.

Payne, Krathwohl and Gordon (1967) used a revised version of the Krumboltz-Weisman (1962) program to teach concepts of educational measurement which contained three sections (percentile norms, z-scores, and validity) of 45 to 60 frames each. Eight experimental groups representing all combinations of logical and scrambled ordering of the three sections did not significantly differ in tests of immediate retention nor two-week retention.

These three studies, revealing no difference in learning difficulty

and retention-transfer, have been criticized -- often by their own authors -- for using "non-sequential" material. An example (Levin & Baker, 1963) is given below:

22. Is this an angle?



23. Do CD and DE make an angle?



24. How many straight lines in this angle?



25. Is this an angle?



Holland (1967, p. 69), in a brief review of these studies, noted: "program error rate for the two sequence forms did not differ, suggesting that the items were not highly interdependent even in the 'sequenced' case, either because of the nature of the concepts taught or because of overcueing." In terms of learner activity, it seems plausible that subjects in the various sequence groups were not performing different cognitive tasks, and hence, with similar "set" and "content" conditions, learned the same thing. Unfortunately, there is no direct test of this admittedly post-hoc suggestion, although it has been found that more highly sequential material does often produce differences in error rate.

Niedermeyer (1968) reported a study by Wodtke, Brown, Sands and Fredericks (1967) in which two types of material -- a sequential program for number bases and a non-sequential program about the human ear -- were taught and tested on a retention-application test. For the non-sequential material, as with the above experiments, scrambling had no effect on learning errors nor post-test performance; however, scrambling did sig-

nificantly increase learning time and errors for sequential material. This latter difference in learning difficulty implies a possible difference in subject activity during learning, however, Wodtke et al. report no differences among the scrambled and normal groups on post-test performance. It appears that either the post-test was insensitive to learning outcome differences, or that the type of differences in cognitive activity in learning scrambled vs. unscrambled material is not the same as nor as important as "search and selection" differences between minimum or method direction Ss vs. answer direction Ss or inductive vs. deductive Ss.

For example, Wodtke et al. argued that scrambling may be an "over-rated variable" and that "...adult Ss are able to relate relevant information as it is made available....". In other words, although it may be harder for scrambled Ss to find the to-be-learned content, once found it is assimilated to the same cognitive set as for unscrambled Ss. The difference between this kind of "search and selection" and that described in previous sections may be that the present type involves searching through content material -- holding parts in rote memory and organizing it -- while the other involves searching through existing cognitive structures.

A similar finding is reported by Neidermeyer, Brown and Sultzer (1969) using "highly interdependent" material in the form of the Gagné-Brown (1961) number series frames. Groups received the frames in logical, scrambled and reverse orders and were tested on retention (10 of the original concepts), and transfer (10 problems in which S had to derive series sum formulae). An analysis of the results, shown in Table 14, reveals that only the differences in learning errors is statistically significant.

TABLE 14

Performance on Learning, Retention and Transfer

for Three Instructional Groups

(Data from Neidermeyer, Brown and Sultz, 1969)

	Learning		Retention	Transfer
	Average Time (min.)	Average Errors	Average Number Correct	Average Number Correct
Logical	78.5	38.2	3.3	3.0
Scrambled	80.9	54.8	1.8	3.0
Reverse	81.5	52.1	2.6	2.1

Jones and Hick (1969), in a program for teaching addition facts to eighth graders, also failed to find any differences between logical and scrambled orderings on a subsequent 20-item test of applications. These findings were summarized by Jones and Hick (p. 69) as follows: "Sequencing programmed instruction in accordance with Skinner's view that small step size is best produced essentially the same performance as the Bruner-Pressey notion, that large variation in step size is best."

One factor limiting the generality of these latter three findings, as well as the other studies in this area, is the short length of the training session. As Neidermeyer et al. (p. 65) pointed out: "...the present study, as well as previous studies lead the authors to believe that for short (less than two hours) programs, sequence may not be as crucial to cognitive outcomes as has previously been thought." It seems obvious but still untested that scrambling larger amounts of material would overtax S to the point of yielding inferior retention-transfer performance; however, it seems that S's performance would more reflect less learning, than a different kind of learning.

Some information about the intellectual requirements of learning scrambled sequences -- what Payne et al. (1967) call the "flexibility and adaptability of the college student" -- comes from a study by Buckland (1968) involving a 50-frame program for teaching base 5 to base 10 conversion to elementary school children. For high ability Ss there were, as in some of the previously cited studies, no significant differences between standard and scrambled groups in learning time, learning errors, retention (tests of base 5 to base 10 conversion problems) or transfer (tests of conversions from new number bases). However, for low ability Ss, presumably less able to search and organize the scrambled material, more learning errors and lower retention-transfer performance characterized the scrambled groups. Apparently, like many of the "minimum direction" Ss, low ability scrambled Ss simply fail to come in contact with the to-be-learned concepts.

Another instance of inferior performance by scrambled Ss comes from a study by Roe (1962) which, using a longer version of the Roe et al. (1962) statistics program, found Ss receiving ordered instruction made fewer errors and took less time in learning, and performed significantly better on post-test measures of retention-transfer. Leaving aside Roe's dubious explanation of why the shorter version failed to produce equivalent results, the strength of these longer version results has been questioned. Niedermeyer (1968, p. 304) notes: "... 'significant difference' for posttest scores turns out to be only ten percentage points... which on the 14-item test he used, is a difference of only one and one-half items... while these differences are statistically different, one wonders whether the magnitude of these differences is large enough to consider the issue closed."

A more striking instance of inferior performance due to scrambling

comes from a study by Brown (1970) which used a version of the Gagné-Brown (1961) series sum program. In an apparent contradiction to the earlier Niedermeier *et al.* study, scrambled Ss scored significantly worse than logical Ss on measures of learning ease (errors and time) and transfer (generating formulae for new series sum problems), as shown in Table 15.

TABLE 15
Performance on Learning, Retention and Transfer
for Two Instructional Groups
(Data from Brown, 1970)

	Learning		Retention	Transfer
	Average Time	Average Errors	Average Number Correct	Average Number Correct
Logical	64.8	7.2	18.5	4.9
Scrambled	80.3	11.8	17.2	3.2

As with the Roe study, the entire claim to inferior learning outcome performance relies on an average difference of about 1.5 items on a transfer test; further studies with larger transfer tests would certainly be useful in demonstrating the fact.

Some evidence for the importance of S's ability to impose a structure on incoming material -- an ability which is seriously taxed by scrambled presentation order -- was provided by Merrill and Stolurow (1966). Using a "programmed problem solving presentation of an imaginary science" made up of a "Xenograde system" containing "satellites," "velocities," and "blips," Merrill and Stolurow found that presenting S with an advance summary of the five to-be-learned principles stated in hierarchical order significantly reduced the number of learning errors and increased transfer performance. Apparently, the advance organizer

helped S find the required "content" more efficiently; however, since Merrill and Stolurow failed to enforce an equal learning criterion across all groups, it seems likely that the performance differences reflect differences in amount learned.

In summary, of the nine studies reviewed, three found no significant differences in learning difficulty or outcome performance, three found significant differences in learning difficulty only, and three found significant differences in learning difficulty and outcome performance for logical vs. scrambled presentation of mathematical problem-oriented material. Based on this box score the following propositions deserve attention: (1) Scrambling increases (especially for difficult, sequential material or low ability Ss) or has no effect on learning difficulty, and has no effect or hurts transfer-retention performance. (2) Ordered presentation decreases or has no effect on learning difficulty and has no effect or helps retention-transfer performance.

When the internal cognitive activity of S is considered, the following propositions should be tested: (1) Scrambling requires S to search and organize the content material, a relatively low level mechanical process which seems to add overall learning difficulty and sometimes surpasses S's intellectual ability. However, the search process is basically a mechanical one that does not greatly influence S's "set" (as does the search of existing knowledge required of minimum-intermediate direction or inductive Ss); hence if S does find the required "content" the learning outcome will be essentially similar to Ss in the ordered condition, and if not, it will be quantitatively less. (2) Ordered presentation simply makes access to the required "content" easier but does not influence S's set. Two factors influencing the importance of scrambling (both related

to S's ability to bridge the scrambling gap) seem to be the type of material -- both the degree of independence across frames and the difficulty -- and learner characteristics and capabilities.

Apparently, Glaser's (1966) claim that the amount of subject error during learning represents an important instructional method variable must be amended to allow for distinctions between errors due to search for content material and errors due to search of existing cognitive structures. Whereas the former seems to result in quantitative differences in learning outcomes (e.g., normal order Ss often learn more than scrambled Ss), the latter seems to result in qualitative differences (e.g., intermediate direction Ss vs. maximum direction Ss). Since all of the scramble studies used "guided discovery" type direction (thus encouraging an active "set") it appears that any differences in learning outcome can be attributed to differences in the amount of content discovered.

Other important questions about the role of subject responses during learning, though only partial indicators of internal activity, have been tested almost exclusively using verbal-text material, and offer informative research routes for testing many of the propositions put forth with regard to learning to solve problems. The main questions are: (1) What is the influence of overt vs. covert responding to interspersed questions? (2) What is the influence of placing review questions before or after relevant instruction? (3) What is the influence of the number of alternatives or the amount of prompting for interspersed review questions? (4) What is the effect of timing, type and amount of feedback?

Control of direction, internal activity and performance: The fourth dimension is the degree of learner vs. experimenter (or teacher) control of the rate and order of presentation. Although a number of experimental

attempts to deal with this problem in problem solving contexts deserve mention (e.g., Lewis & Pask, 1965; Evans, 1965; Kress & Gropper, 1966; Coop & Brown, 1970) and the theoretical importance of this issue has been discussed (Bruner, 1961), there is an insufficient literature of laboratory problem-solving studies at this time. One of the motivations for such studies is an opportunity to more closely investigate the relation between learner activity (and by inference, internal activity) and learning outcomes.

The Unconclusion

The future of the instructional method problem is unclear. It is clear, however, that little progress will be made until the suffocating emphasis on "which method is best" gives way to an attempt to define and relate to one another, external features of instruction, internal features of subject character and activity during learning, and outcome performance variables.

This review seems to indicate that the most developed findings to date deal with the dimension of amount and type of direction, with the dimensions of sequencing and of structuring less well investigated, and the dimension of control fairly unstudied.

In the flow chart given in Fig. 1, a simplified model of the encoding process is given. The two conditional branches represent Ss ability to come into contact with the to-be-learned content and the breadth of S's assimilative set. In essence, the determination of how instructional variables affect these two conditional processes (and hence the learning outcome) is the future challenge of the instructional method problem.

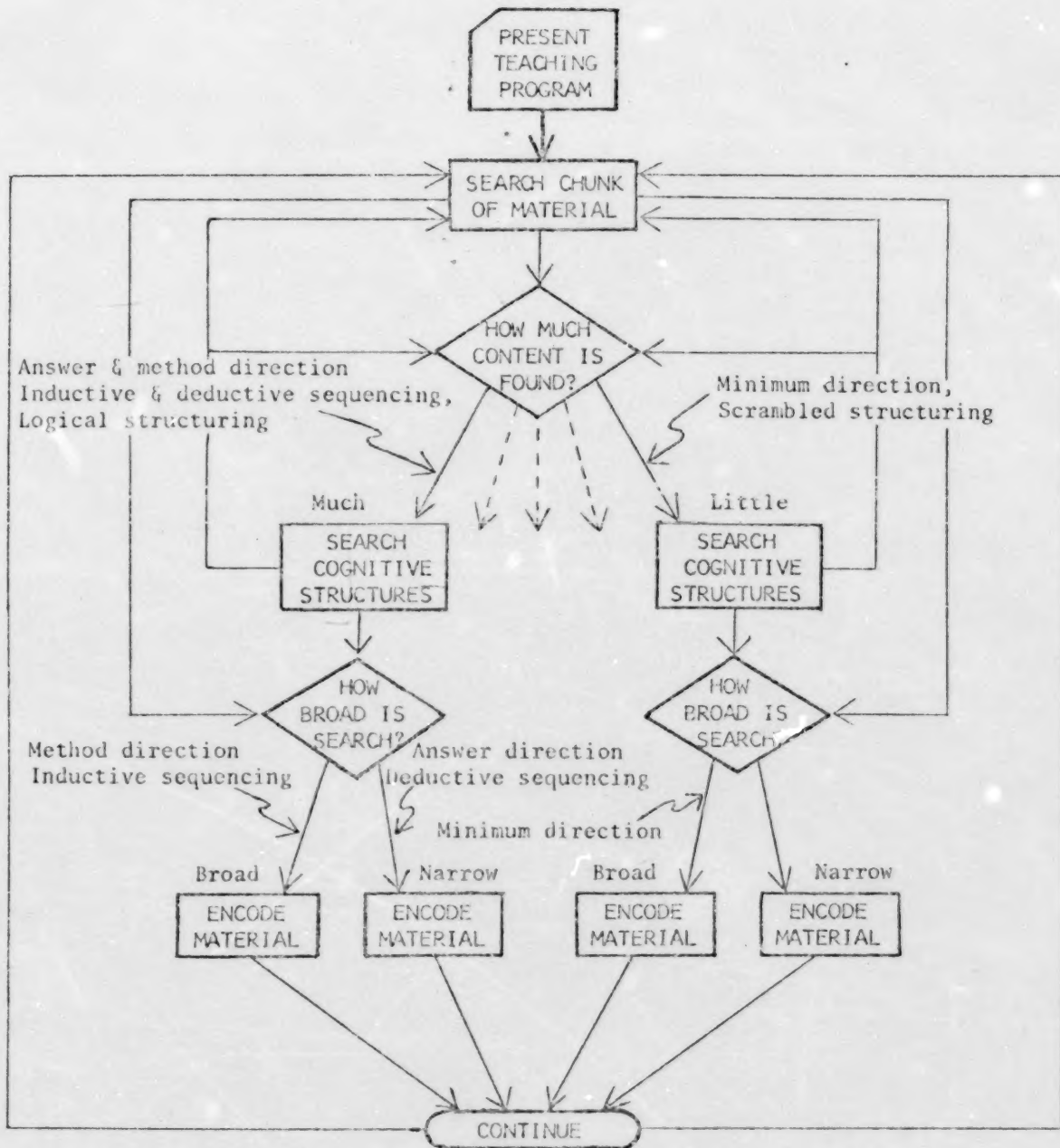


Fig. 1. Flow chart showing hypothetical encoding processes of learning.

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